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(71) Applicant *(for all designated States except US)*: **NORSK HYDRO ASA** [NO/NO]; N-0240 Oslo (NO).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **ÅSHOLT, Petter** [NO/NO]; Håsenveien 22, N-6600 Sunndalsøra (NO). **TOKLE, Gunnar** [NO/NO]; Landstøveien 11, N-6600 Sunndalsøra (NO).

(74) Agent: **BERG, André**; Norsk Hydro ASA, N-0240 Oslo (NO).

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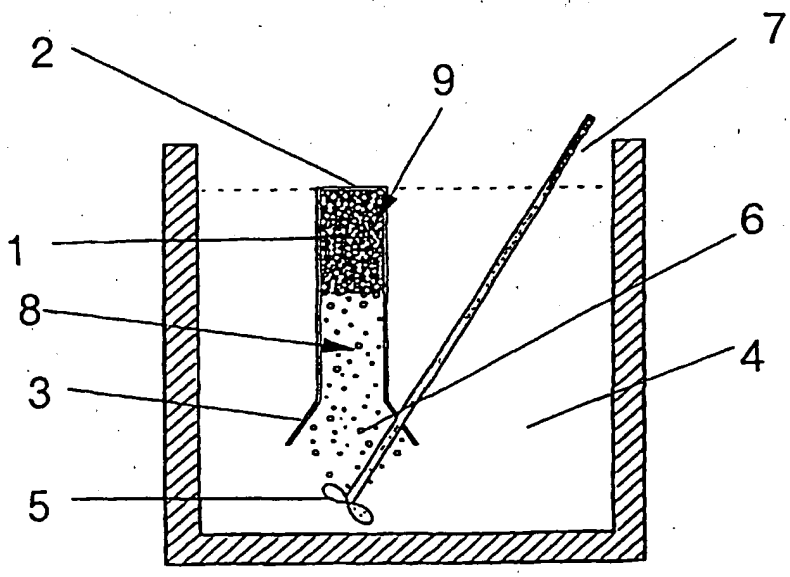
(54) Title: A METHOD AND MEANS FOR PRODUCING MOULDED FOAM BODIES



(57) Abstract: Present invention relates to a method and means for producing moulded bodies of a metal foam (9), in particular an aluminium foam. The method involves the use of a mould (1) having a cavity (8) and at least one entrance opening (3). The mould is filled with a metal foam in a manner where the entrance opening of the mould is submerged into a metal melt (4) and the melt is caused to foam inside the mould (1) and fill its cavity (8).

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A method and means for producing moulded foam bodies

Present invention relates to a method and means for producing moulded bodies of metal foam, in particular an aluminium foam.

Up to present, several techniques have been proposed for the production of three-dimensional bodies of metal foam. For instance in US 5,865,237 there is disclosed a method for making foam casting objects where a volume of foaming compacts of a powder metal and a gas-evolving foaming agent is heated in a chamber. When at least partial foaming occurs, the contents is forced into a mould cavity where residual foaming is permitted.

In Norwegian Patent No. 304359 there is disclosed a method for casting articles by heating a metal matrix composite that contains finely dispersed solid stabilising particles to a temperature above the solidus temperature for the metal matrix. Gas bubbles are introduced into the melted metal composite beneath the surface thereof, whereby a stabilised flowable metal foam is obtained on the surface of the metal composite. Further, the stabilised metal foam that is in a liquid state is thereafter forced into a form cavity where it is allowed to cool and solidify.

These methods implies that the foam is forced or pressed into the mould cavity. In dependency of the shape of the mould cavity, inhomogenity in the foamed body may occur as a result of restricted inflow and frictional forces between the moving metal and the internal mould walls in the cavity under the filling operation. In addition, related to complex tree dimensional shapes of the cavity, there can be problems with insufficient filling of the mould causing that the cast product will not be complementary with the mould cavity.

According to the present invention, there is provided a novel and simplified method of forming three-dimensional castings of foamed metal, where problems of the above mentioned type can be minimised.

In the following, the invention shall be further described by examples and figures where:

Fig. 1 shows a mould completely submerged into a melt,
Fig. 2 shows a mould semi submerged into a melt,
Fig. 3 shows a porous plug generating bubbles,
Fig. 4 shows the upper part of a mould having an air outlet.

In Figure 1 the mould 1 consists of a vertically arranged cylindrical shell with a closed top 2. The mould shown here is completely submerged, and its cavity 8 is filled with melt 4 before the melt is foamed. The lower part of the cylindrical mould is formed as a diverging or conical shell representing the entrance 3 of the mould. In the melt, below the entrance of the mould there is arranged a rotor impeller 5 of a type that delivers gas through outlets in the vicinity of the impeller or through outlets in the impeller itself. The impeller 5 rotates about an axle 7 that may comprise an internal pipe for leading gas to the impeller (not shown). Under the foaming process the delivered cellulating gas forms bubbles 6 that rises upwards and enters the mould 1. The bubbles continue to rise until they reach the upper end wall 2 of the mould. There the bubbles accumulate, and after a period of foaming the melt in the mould will be completely foamed. In the figure, foamed metal 9 is indicated in the upper half-section of the mould.

It should be understood that the above mentioned principle of gas injection, which is commonly known by those skilled in the art and further described in the applicants own patent application WO 91/01387, may be substituted by other ways of gas injection that will generate foaming. The use of a porous plug in this sense will be described later.

Coalescence of the bubbles accumulated in the mould can be avoided by addition of refractory particles in the melt matrix that reinforce the bubble walls. As shown in the example, the mould is completely filled with melt before the foaming starts up. This results in the fact that no air will be present in the mould before foaming which contributes to reduce possible friction between the foam and the mould walls during the moulding process that may cause unwanted structural deformations of the foam.

In a second embodiment which is shown in Figure 2 a mould 100 is semi-submerged into a melt 104, where the entrance 103 of the mould is located beneath the surface of the melt. The mould in this embodiment has the same shape as that of Figure 1, with a top 102 and a diverging or conical open entrance 103. In this situation the foaming of the

melt by the rotor impeller 105 will start following that the mould cavity has been sufficiently filled with molten metal.

As indicated in figure 4, the mould 403 may in addition be provided with an air outlet or evacuating means in the top thereof for evacuating air before and/or under appropriate periods of the melt filling and foaming operation, to assist the level increase in the cylinder to be higher than the level of the ambient melt. Such evacuating means may comprise a controllable outlet such as an air vent screw or a valve 400. The figure shows an upper part of the mould 403 with a cavity indicated by 402. The mould wall 401 is penetrated in its upper region by a pipe 404 connected with the valve 400. The valve 400 may further be connected with evacuating means such as a vacuum pump (not shown).

An alternative way of filling the mould with melt without the use of specific air evacuating means is to turn the mould upside down and back again while it is submerged in the melt.

Alternatively, the mould may be dividable into two or more parts (not shown). The latter will ease filling of the mould with melt before foaming, and make the casting of complex three dimensional components available. With a dividable mould, the mould should preferably be divided during submerging in the melt to ease filling. After submerging, the mould is closed by sliding the parts together, leaving a fully filled cavity. After foam filling the mould is lifted from the melt to solidify the foam body, and the mould is again divided to remove the foam body.

After the foaming process where the melt inside the mould is replaced by foamed metal, a lid or the similar may preferably be placed under the bottom part to ensure that the net shape foam component still in liquid or semi solid state does not fall out as the mould is fully extracted from the melt to solidify and cool the foam inside.

The mould may preferably be preheated before being submerged in the melt in order to reduce dead time before foam filling. This could be done by integrated heating elements in the mould, for instance electric heating elements. Alternatively, the mould or mould parts could be heated in a separate chamber. Likewise, the mould could be equipped with an integrated cooling circuit to cool the mould subsequent to foam filling to reduce time for solidification before the foam body is removed from the mould.

During experiments, it was observed that surface quality varies along the length of the cast components. This is due to the fact that the mould was fixed at the same vertical level during the foaming operation. As the best surface quality was found near the bottom of the components, it is assumed that the observed differences in surface quality is closely linked to the metallostatic pressure in the position where the surface is created. The foam bodies produced by this method have a smooth outer surface in the parts of it that solidifies next to the mould walls, while the interior of the foam body is, of course, porous. An improvement of the all over surface quality is therefore assumed to be achieved if the mould is elevated during foam filling in such a way that the lowermost foam inside is always at the same depth. In this way, the pressure will always be the same where the new foam is accumulated. The mould may be lowered and elevated by an electric hoisting apparatus (not shown).

In the above standing examples there is disclosed a mould of cylindrical shape, but it should be understood that other geometrical shapes can be applied as well.

With the present method, one can cast an aluminium core inside another (hollow) metallic part or the similar, e.g. foam filling inside a steel tube in a crash box for energy absorption applications where the steel tube will serve as the mould in the manufacturing process. Provided that the metallic part can survive staying in the melt for some time (as it is or with some surface treatment), one could imagine to fill such components directly by the present method. This would rationalise the manufacturing process of foam filled hollow components significantly.

Yet another possibility is to use another source for generating the bubbles for foaming, for instance porous plugs or plates, where the gas is injected into the melt from these devices. This could ease the process control as the gas could more easily be turned on and off when needed, for instance in the dead time during mould exchanges. Figure 3 shows this principle for generating foam, where a gas generating device 305 generates bubbles 300 in a melt. The device comprises a porous plug 302, for instance of a ceramic medium or other appropriate material, arranged above a gas distribution chamber 301 having a gas inlet 304. The principle is that the foaming gas is forced through the porous ceramic medium, leading to bubble formation on the opposite side i.e. in the melt.

It should be understood that in accordance with the present method other varieties of products can be made, such as tubes and other products with hollow cross-sections.

Even products having cross-sections with an U-profile can be made by the method. This can be implemented by the arrangement of an insert in the mould before filling (not shown).

As will be understood on the basis of the above standing paragraphs, the mould itself can preferably be of a re-usable type, or it can simply be a part of the component intended to receive the foam.

Claims

1. A method for producing moulded bodies of a foamed metal, in particular an aluminium foam, where a mould (1) having a cavity (8) and at least one entrance opening (3) is filled with a metal foam (9),
characterised in that
the mould (1) is filled with melt (4) before foaming, after which the mould is filled with foam (9) by accumulation of separate bubbles rising through the melt (4), while keeping at least the entrance opening (3) submerged in the melt.

2. A method in accordance with claim 1,
characterised in that
the mould (1) is raised vertically during foaming.

3. A method in accordance with claim 1,
characterised in that
the mould is evacuated before and/or under the filling/foaming process.

4. A method in accordance with claim 1,
characterised in that
the bubbles are generated by appropriate means (5, 305) arranged in the melt (4) below the entrance opening (3) of the mould (1).

5. Means for producing moulded bodies of a metal foam (9), in particular an aluminium foam, comprising a mould (1) having a cavity (8) and at least one entrance opening (3) for the filling with a metal foam (9), the means further comprising a metal melt (4) and means (5, 305) for injecting a gas into the melt (4) to cause foaming,
characterised in that
the mould (1) is arranged at least with its entrance opening (3) submerged into the melt (4) under its filling.

6. Means in accordance with claim 5,
characterised in that
the mould is divided comprising two or more parts.

7. Means in accordance with claim 5,
characterised in that
the mould is further provided with means (400, 404) for draining/evacuating air out of the mould cavity (402).

8. Means in accordance with claim 5,
characterised in that
the mould has provisions for heating.

9. Means in accordance with claim 5,
characterised in that
the mould has provisions for cooling.

10. Means in accordance with claim 5,
characterised in that
the means (305) for gas injection during foaming comprises porous plates (302) or plugs.

11. Means in accordance with claim 5,
characterised in that
the means for gas injection during foaming comprises a rotor impeller (5) with one or more gas outlets.

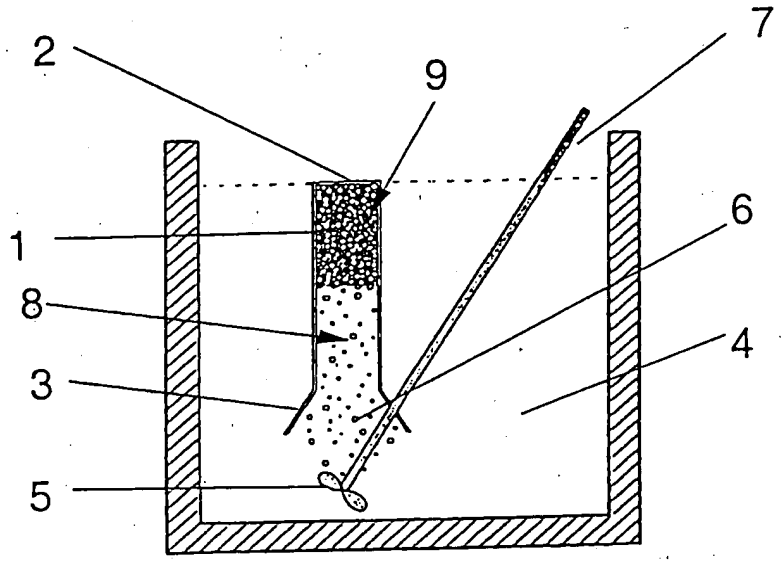

Fig. 1

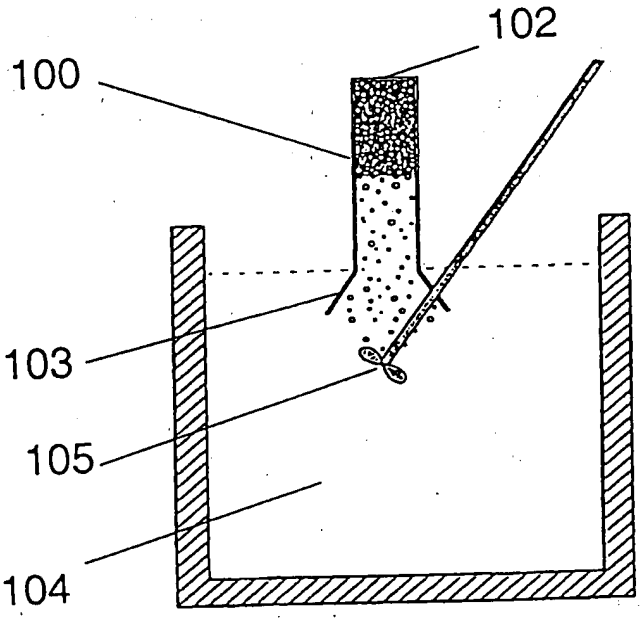

Fig. 2

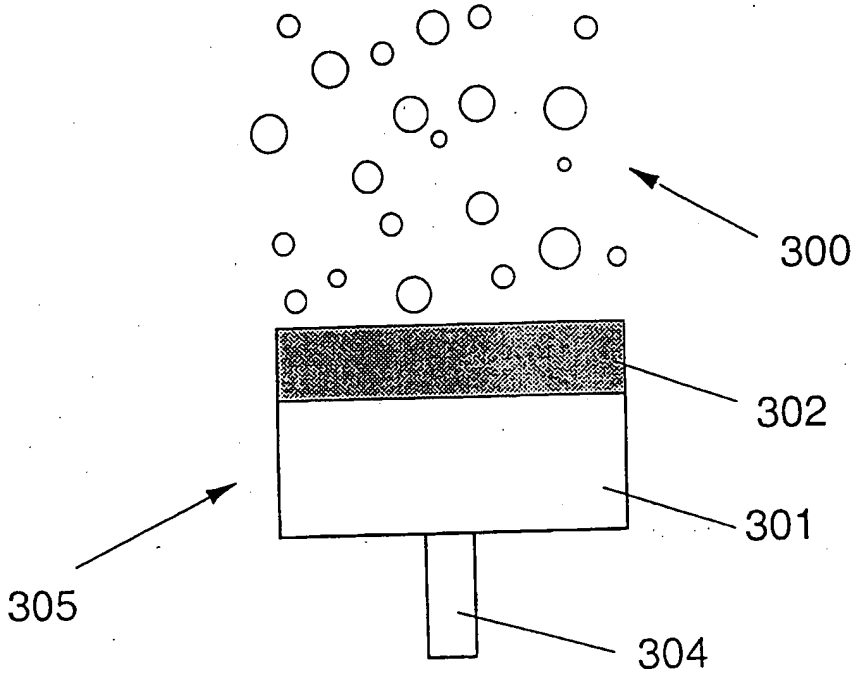

Fig. 3

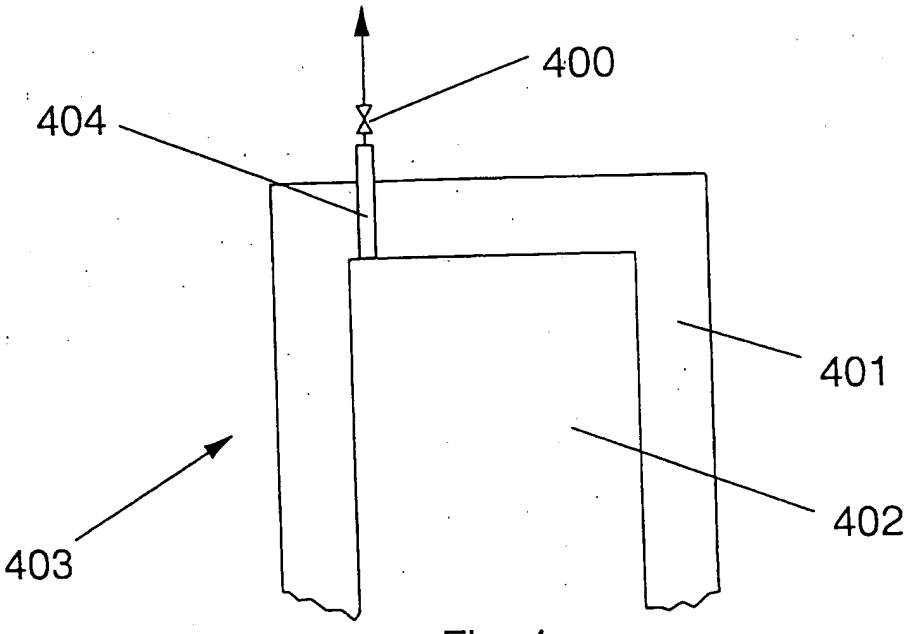

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 01/00072

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B22D 25/00, C22C 1/08
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B22D, C22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 4326982 C1 (ALCAN DEUTSCHLAND GMBH), 9 February 1995 (09.02.95), column 4, line 41 - column 5, line 15; column 5, line 53 - line 59, figure 3, abstract --	1,2,4-7, 10 12
A	GB 892934 A (LOR CORPORATION), 4 April 1962 (04.04.62), page 2, line 52 - line 128, figures 1-3 --	1-12
A	WO 9221457 A1 (ALCAN INTERNATIONAL LIMITED), 10 December 1992 (10.12.92), figures 1-9, claim 1, abstract -- --------	1-12

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 May 2001	07 -06- 2001
Name and mailing address of the ISA: Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Ulf Nyström/ELY Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 4326982 C1	09/02/95	NONE	
GB 892934 A	04/04/62	NONE	
WO 9221457 A1	10/12/92	AT 140169 T	15/07/96
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